PART FIVE

Continuous $PM_{2.5}$ Chemical Speciation Monitoring

Chapter 7
Part Five - Continuous $PM_{2.5}$ Chemical Speciation Monitoring
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Part Five – Continuous $PM_{2.5}$ Chemical Speciation Monitoring

1.0 Introduction

Along with toxics, carbonyls, ozone precursors and meteorological data; $PM_{2.5}$ chemical speciation is considered a Non-Criteria parameter. Chemical speciation sites help:

- Provide more specific data to define the correlation between particle concentration/composition and public health concerns
- Recognize national trends
- Identify source/receptor relationships and determine the effectiveness of emission control strategies
- Access air quality models and emission inventories
- Support future revisions to the National Ambient Air Quality Standards (NAAQS)

Currently the state operates continuous speciation monitors at 5 sites. The following part of Chapter 7 is intended to outline the monitoring, quality assurance (QA), and quality control (QC) practices associated with continuous chemical speciation sampling. Further information can be found in CFR 40 Part 58.

1.1 Sampling Method Overview

1.1.1 Aethalometer

The Aethalometer provides the capability of continuous monitoring of a variety of carbon species. The models used in Indiana's air monitoring network allow measurement in two wavelengths of light; 880 nm (infrared) and 370 nm (ultraviolet). This distinction can aid in determining the source of carbon; diesel exhaust, wood smoke, etc. The Aethalometer uses filtration and optical measurement to provide continuous concentration data.

2.0 Instrumentation

2.1. Interferences

The Aethalometer is designed to limit outside interferences. It can be affected by high levels of mineral dust. While mineral dust has not been found to contain high levels of black carbon, it has an absorption cross-section, that if found in concentrations 100 to 1000 times greater than black carbon can produce a comparable optical absorption.

2.2. Instrument Description

2.2.2 Aethalometer

The Aethalometer is made up of an inlet and the monitor itself. The inlet requirements are not especially stringent; typically only a bug shield and/or filter is required. The ambient black carbon's size (approximately 0.3 µm diameter) is small enough to not be adversely affected by an impactor (such as a $PM_{2.5}$ very sharp cut cyclone) and large enough to mitigate loss due to diffusion to the tubing walls between the inlet and monitor. The run from inlet to monitor should be less than thirty feet. Upon entering the monitor, the sample gas is pulled through a quartz fiber filter tape, where the aerosol black carbon is deposited. The Aethalometer continually analyzes the sample gas as the sample is collecting. Once the filter tape has reached a set density, it advances. In an urban setting, this could take place 3-4 times a day. The tape may only advance once a day in more rural locations. The Aethalometer passes a beam of light through the sample depositing on the filter tape. The detector measures the amount of light transmitted through the sample. This quantity is linear proportional to the black carbon in the filter deposit. This is shown on the instrument as a concentration.

2.3. Ancillary Equipment

Listed below are several (but not all inclusive) supplies required for operation of IDEM's monitoring network:

- Certified flow rate transfer standards (Bios, TriCal, or similar)
- Certified barometer (digital or aneroid)
- Certified thermometer (digital or liquid)
- Logbooks and database/laboratory and maintenance
- Manufacturer recommended spare parts
- Standard time piece of known accuracy within ±2 min/24hr.

3.0 Site Selection

3.1. Siting Requirements

Basic siting criteria for the placement of ambient air samplers are documented in Table 1 in this section. This is not a complete listing of siting requirements; instead, an outline to be used by the operating agency to determine a sampler location. Complete siting criteria are presented in 40 CFR 58, Appendix E. All sampling locations must meet the guidelines set forth in 40 CFR Part 50 Appendix L, and Part 58 Appendix D as well as the siting guidelines outlined in Chapter 1, Section 4.0 of this manual.

As with any type of air monitoring study in which sample data are used to draw conclusions about a general population, the validity of the conclusions depends on the representativeness of the sample data. Therefore, the primary goal of a monitoring project is to select a site or sites

where the collected particulate mass is representative of the monitored area.

Table 1
Example of Minimum Sampler Siting Criteria

Scale	Height Above Ground	Distance from supporting structure, meters		Other spacing criteria
		Vertical	Horizontal [a]	
Micro	2 to 7 meters	>2	>2	1. Should be >20 meters from trees.
Middle, Neighborhood, Urban, & Regional	2 to 15 meters	>2	>2	2. Distance from sampler to obstacle, such as buildings, must be twice the height that the obstacle protrudes above the sampler.
				3. Must have unrestricted airflow 270 degrees around the sampler inlet.
				4. No furnace or incineration flues should be nearby.[b]
				5. Spacing from roads varies with traffic (see (40 CFR 58, Appendix E)).

[a] When inlet is located on rooftop, this separation distance is in reference to walls, parapets, or penthouses located on the roof.

[b] Distance depends on the height of furnace or incineration flues, type of fuel or waste burned, and quality of fuel (sulfur, ash, or lead content). This is to avoid undue influences from minor pollutant sources. As a precautionary measure, the sampler should be placed at least 5 meters from the furnace or incinerator flue.

3.2. Site Safety and Security

Additional factors not specified in the Code of Federal Regulations (CFR) must be considered in determining where the monitor is deployed. These factors include accessibility under all weather conditions, availability of adequate electricity, and security of the monitoring personnel and equipment. The monitor must be situated where the operator can reach it safely despite adverse weather conditions. If the monitor (or part of the monitor i.e., sample inlet) is located on a rooftop, care should be taken that the operator's personal safety is not jeopardized by a slippery roof surface during inclement weather. Consideration also should be given to the fact that routine operation (i.e., calibration, maintenance, flow check, and audit) involves transporting supplies and equipment to and from the monitoring site.

To ensure that adequate power is available, consult the manufacturer's instruction manual for the sampler's minimum voltage and power requirements. Lack of stable power source can result in the loss of data because of power interruptions.

The security of the sampler itself depends mostly on its location. Rooftop sites with locked access and ground-level sites with fences are common. In all cases, the security of the operating personnel as well as the sampler should be considered.

4.0 Monitor Installation, Calibration, and Operation

4.1. Monitor Installation

All site selections and installations shall comply with siting criteria presented in 40 CFR 58, Appendix E. Installation should also adhere to section 3.2 Site Safety and Security in this document. The following is a general guideline for instrument installation. More detailed instructions should be referenced in their corresponding manuals.

Once a site has been selected and the instrument tested and found to be in working order:

1. Determine the exact location of the monitor and all included equipment. Care should be taken to allow room for both sample and electrical connections.
   - Does not need to be placed directly below a down tube.
2. Drill or use an existing opening in the structure's roof or wall to allow for the instruments' inlet tube. In addition, mount the tripod or other down tube support structure, if needed.
3. Inside the shelter, mount the instrument on a rack using the appropriate hardware, or place on a sturdy flat surface, such as a table or counter top.
   - If not rack mounting, be sure to properly secure the instrument to account for vibrations
4. Make all electrical, communication, and air connections. Be sure all packing material, shipping screws, and other similar materials have been removed prior to turning on.
5. Once installed, power on, allow instrument to warm up, and ensure that all functions are working properly.

4.2. Calibration of Components

4.2.1 Overview of Calibration Procedures

The following is a general guide to calibrating the continuous monitors used by IDEM. For more detailed instructions, refer to the specific monitor's user manual and the IDEM OAQ instrument specific SOP(s).

4.2.2 Aethalometer Calibration Procedure

Equipment required for calibration:

- Certified thermometer/temperature probe
- Certified barometer
- Certified flow transfer standards (BIOS or similar)
- Calibration/audit line
- Optical test strip
- Calibration form
- Standard time piece of known accuracy within ±2 min/24hr.

The only calibration required during the normal operation of the Aethalometer is a flowmeter calibration. Flowmeter calibration is only needed if the true flow is suspected of being > ±10.0% different from the displayed flow. However, during the calibration, the site operator needs to confirm the time is within ±1 minute and the date is correct and adjust if needed, making note of this.

Magee Flowmeter Calibration:

1. Disable the corresponding channel in the Leading Environmental Analysis Display System (LEADS).
2. Remove the sample line from the rear of the Aethalometer and replace with a calibration/audit line attached to a certified flow transfer standard.
3. Record the ambient conditions; shelter temperature and pressure on the calibration form.
4. On the Aethalometer, navigate the menu to “Calibrate Flowmeter” and press ENTER. Select “YES.”
5. Remove the vacuum line from, or unplug the electrical connection of the internal pump.
6. Allow instrument to equilibrate for at stable “zero voltage” After a short time, the zero voltage is automatically measured.
7. Plug in the pump to resume air flow.
8. Allow instrument to equilibrate once again. After flow is stable, use the “Burst” measurement on the BIOS to determine a reference flow. Record this flow on the Aethalometer Calibration Form.

   Note: Make sure the flow on the transfer standard is in actual conditions or standard conditions based on how the flow on the Aethalometer is set up .
9. If the reference flow is within ±10.0%, no calibration is required, and the instrument can be returned to service. It is recommended that the difference be within ±5.0% to avoid any potential drift which could cause data loss.
10. If displayed flow value is outside ±10% use the arrow keys to change the flow scale factor to read the same as the reference flow. Press ENTER to change and retain the new flow scale factor.

11. Exit back to the main menu.
12. Use the BIOS to test the flow from the back of the unit. Note the results in the "As Left" section of the calibration form.
13. Replace the sample line. Allow the Aethalometer to equilibrate, then repeat the BIOS flow check from the inlet and note results in the "As left… through the probe" section of the calibration form.
14. Enable the corresponding LEADS channel and leave an electronic operator log entry.

API Flowmeter Calibration:

1. Before a calibration can be performed, a leakage test must be completed.
2. Navigate the menu OPERATION>ADVANCED. Select FLOWCAL, then MANUAL
3. After the chamber lifts, remove the tape and insert the flow calibration pad. Press OK and the chamber will close.
4. Connect a certified flow meter to the API's inlet and press OK. Allow the pump to achieve a stable flow.
5. Enter the flow value from the flow meter into the blank FLOW field using the on screen keyboard, then adjust the temperature and pressure to EPA standard. Press OK.
6. Again, wait for the flow to stabilize. Once stable input the flow meter's reading then select OK.
7. Repeat for the third point. Press OK. At this point the calibration is complete. The sampling head will lift.
8. Remove the calibration pad and return to the HOME screen..
9. If the instrument displays any faults post calibration, cycle the power. Return the unit to operational status by selecting START from the OPERATION>GENERAL screen.

4.3. Monitor Operation

Each monitor should be operated in accordance with the user's manual. In general, each should:

1. Be properly sited (refer to section 3 in this part)
2. Be connected to a reliable power source
3. Have a valid calibration prior to collecting usable data

5.0 Data Acquisition

Data is collected using a compact flash card (Magee) or USB thumb drive (API). The data is brought back to the station to be reviewed, checked for quality, and put into proper AQS format for submittal.

6.0 Data Validation

Data validation criteria were developed from the instruments' operation manual recommendations and from staff's operational experience. In general, if the instrument is operating with a valid calibration, has passed QA/QC audits, and is operating without alarms, warnings, or status lights, it is considered capable of producing valid data.

7.0 Verification and Performance Audit Procedures

The primary goal of a verification and auditing program is to identify problems that may result in suspect or invalid data. The verification checks are performed by the operating agency, who also performs the calibrations. Audits must be performed by another group independent of performing the calibrations. Verifications and audits should be conducted under the following guidelines:

- Audits must be done without special preparation or adjustments made to the system.
- The individual performing the audit should be someone other than the routine operator and must have a thorough knowledge of all instruments or processes being evaluated.
- All aspects of the verification and audit must be completely documented including the types of instruments and transfer standards, model and serial numbers, calibration information, etc.
- The Aethalometer samplers in the State of Indiana's Ambient Monitoring Network have verifications performed monthly by the Ambient Monitoring Sections, and audits performed quarterly by the Quality Assurance Section.

Verifications and audits should start at the beginning of an hour or at least completed during the hour to minimize data loss.

7.1 Verification and Audit Procedures

7.1.1 Verification and Audit Equipment

- Certified flow transfer standard (BIOS or similar).
- Certified digital or aneroid barometer
- Certified temperature probe or thermometer
- Verification or audit Form
- Standard time piece of known accuracy within ±2 min/24hr.

Equations

Table 2
Conversions

mmHg to atmospheres (atm)	mmHg/760
atm to mmHg	atm* 760
°C to Kelvin (K)	°C + 273

Standard Temperature/Pressure (SRC) Flow correction

$$Q_{true} = Q_{ob}\left[\left(\frac{293}{T_{amb} + 273}\right)\left(\frac{P_{amb}}{760}\right)\right]$$

Where:

Q_{true} = True Flow rate, m^3/min
Q_{ob} = Observed Flow Rate, m^3/min
P_{amb} = Ambient barometric pressure, mmHg
T_{amb} = Ambient Temperature ˚C

$$\%\ Difference = \left[\frac{(Q_{ob} - Q_{true})}{Q_{true}}\right] * 100$$

Where:

Q_{true} = True Flow rate, m^3/min
Q_{ob} = Observed (Sampler) Flow rate, m^3/min

If the sampler requires the conversion of actual/standard flow, use the following equation:

$$Q_{std} = Q_a(P_a/P_{std})(T_{std}/T_a)$$

$$Q_a = Q_{std}(P_{std}/P_a)(T_a/T_{std})$$

Where:

Q_{std} = standard volume flow rate, m^3/min
Q_a = actual volume flow rate, m^3/min
P_a = ambient barometric pressure, mmHg
P_{std} = standard barometric pressure, 760 mmHg
T_{std} = standard temperature, 298 K (25 °C + 273)
T_a = ambient temperature, K (°C + 273)

Difference, in Percent calculation

$$Diff = \left(\frac{V_{Obs} - V_{Ref}}{V_{Ref}}\right) \times 100$$

Where:

V_{Ref} = Reference Value
V_{Obs} = Observed Value
Diff = Difference in percent

SO_2 Concentration Calculation

$$[SO_2]_{out} = \frac{F_{SO_2} * [SO_2]_{std}}{F_{SO_2} + F_d}$$

Where:

$[SO_2]_{out}$ = output concentration of SO_2 measured in ppm
$[SO_2]_{std}$ = certified concentration of the SO_2 gas cylinder measured in ppm
Fso_2 = cylinder flow of the SO_2 gas measured in cc/min at SRC
F_d = flow of the dilution gas (zero air) measured in cc/min at SRC

7.2 Overview of Verification and Audit Procedures

The following is only a general guide, for more detailed, sampler specific instructions, refer to the user's manual and instrument specific SOPs.

7.2.1 Magee Scientific Aethalometer Verification and Audit Procedures

1. Disable the corresponding LEADS channel. The sampler time must be within ±5 minutes of the local standard time. For the verification, if >5 minutes adjust the time and make note of this. Also, confirm the date is correct and if needed, adjust the date and make note of this. For the audit consult with the site operator if the date and time do not meet specifications and make note of this.
2. Perform a through the probe flow check from the inlet. Remove the inlet and place a certified BIOS (or similar) in-line.
3. Allow the instrument flow to equilibrate.
4. Record the ambient temperature and pressure using a certified temperature probe or thermometer and barometer.
5. Use the "Burst" mode on the BIOS to take an average of 10 flow measurements. Use the formula above to convert flow to SRC. Record the BIOS' displayed flow and the SRC corrected (reference) flow on the verification or audit form
6. Record the Aethalometer's observed flow. The reference should be within ±10% of the observed flow. Replace the inlet.
7. If the percent difference is lower than 10.0% skip to step 11, otherwise continue

8. Remove the sample line from the back of the unit and replace with the BIOS.
9. Allow the instrument flow to equilibrate.
10. Repeat the flow audit as above. Record results on the verification or audit form. A significant discrepancy in the through the probe and back of the instrument flow results could indicate a leak in the system.
11. Remove the BIOS and return the sample line. Allow the Aethalometer at least 15 minutes to equilibrate before returning to service.
12. Enable the corresponding LEADS channel and leave an electronic operator log entry. Contact the parameter specialist if the flow does not meet specifications.

7.3 Verification and Audit Data Reporting

Verification and audit results should be reported to appropriate personnel as soon as possible after completion. A paper copy of the verification or audit may be forwarded to the operator or personnel may view the results in the database. If data is invalid, the auditor should promptly inform the operator verbally and in written form (memo or email).

7.4 Audit Frequency

The Indiana Department of Environmental Management conducts monthly verifications and quarterly QA audits of all real-time speciation monitors in its network to ensure minimal data loss.

7.5 Systems Audit

A system audit is review of the total monitoring process from site location, safety, and sampling to final analysis and data reporting and includes an on-site inspection. System audits are generally done at the initial set up of a network and on an annual or on an as needed basis thereafter. The specific guidelines and procedures for this type of audit are found in Chapter 15 of this manual, System Audit Criteria and Procedures for Evaluating Ambient Air Monitoring Networks.

8.0 Precision and Accuracy Assessment

8.1 Precision

Precision is the measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is estimated by the use of a duplicate or collocated sampler at a selected monitoring location in a measurement network. One sampler is designated as the reporting sampler and one sampler is designated as the collocated sampler. The collocated sampler must be maintained, operated, calibrated, and audited in the same manner as the reporting sampler. Precision is calculated from the difference in the concentrations from the reporting and collocated samplers over a calendar quarter. Currently, no

collocated real-time speciation monitors are in use within Indiana's ambient monitoring network. They are all, however, operated at sites which also consist of intermittent speciation monitors.

8.2 Accuracy

The USEPA requires that 25 percent of the samplers within a reporting organization's network be audited for accuracy each quarter. To improve accuracy estimates, additional accuracy flow rate audits may be conducted each calendar quarter. IDEM-OAQ-QAS audits all continuous speciation samplers in its monitoring network at least once per quarter. This audit frequency provides additional accuracy flow rate data and also ensures minimal data loss due to "out-of-calibration" conditions.

9.0 Maintenance

Routine preventive maintenance helps prevent failures of the monitoring processes. The overall objective is to increase measurement reliability and prevent data loss. Follow the manufacturer's recommended guidelines for routine maintenance procedures.

Maintenance records must be kept for each sampler or instrument. These records should contain a history of the sampler, including all replacement parts, suppliers, costs, installation dates, etc.

9.1 Recommended Maintenance and Frequency

Table 3
Aethalometer Recommended Maintenance

Maintenance	Frequency
Optical Sampling and Analysis Cylinder cleaning	1-2 Years as needed
Bypass Filter Cartridge Replacement	1-2 Years as needed
Sample line	Replace on 1 to 4 year cycle

9.2 As Needed Maintenance

- Exchange fuses
- Clock adjustment
- Resetting system
- System software download

10.0 Forms

Form 1:
Magee Scientific Aethalometer Calibration Form

IDEM

Aethalometer Annual Calibration
Office of Air Quality - Air Monitoring Branch

Date: _____ Site: _____ AQS#: _____

Start time: _____ End time: _____ Performed by: _____

Aethalometer Brand & Model: **Magee Scientific** / _____ Serial Number: _____

Calibration Device Information

Flow Device SN: _____ Certification Date: _____

Thermometer SN: _____ Certification Date: _____

Barometer SN: _____ Certification Date: _____

As found calibration check through the probe

Ambient Temperature: _____ °C Barometric Pressure _____ mmHg

Aethalometer Display: _____ lpm Observed Flow

Flow Device Display: _____ lpm Flow not corrected to STP

True Flow: _____ lpm Flow corrected to STP

% Difference: _____

≤10% = in cal, data valid; >10% but ≤15% = out of cal, data valid; >15% out of cal, data invalid

As found calibration check back of unit

Ambient Temperature: _____ °C Barometric Pressure _____ mmHg

Aethalometer Display: _____ lpm Observed Flow

Flow Device Display: _____ lpm Flow not corrected to STP

True Flow: _____ lpm Flow corrected to STP

% Difference: _____

≤10% = in cal, data valid; >10% but ≤15% = out of cal, data valid; >15% out of cal, data invalid

Formulas & Conversions

$$\text{True Flow} = \text{Flow Device} * \left[\frac{293}{(\text{Amb Temp} + 273)}\right]\left[\frac{\text{Baro Press}}{760}\right]$$

$$\%\ \text{Difference} = \left[\frac{\text{Observed Flow} - \text{True Flow}}{\text{True Flow}}\right] * 100$$

Conversions: °C = (°F - 32) * 0.5556 mmHg = " Hg * 25.4
°K = °C +273

Standard Conditions: 20 °C (293 °K) 760 mmHg (29.92 " Hg)

Magee Scientific Aethalometer Calibration Form (Continued)

Maintenance prior to "As Left Calibration"

Cleaned Optics area _____

Cleaned bug filter _____

Replaced Bypass Cartridge Filter _____ (every 2 years)

As left calibration check back of unit

Ambient Temperature: _____ °C Barometric Pressure _____ mmHg

Aethalometer Display: _____ lpm Observed Flow

Flow Device Display: _____ lpm Flow not corrected to STP

True Flow: _____ lpm Flow corrected to STP

% Difference: _____ Pass if % Difference < 10%

As left calibration check through the probe

Ambient Temperature: _____ °C Barometric Pressure _____ mmHg

Aethalometer Display: _____ lpm Observed Flow

Flow Device Display: _____ lpm Flow not corrected to STP

True Flow: _____ lpm Flow corrected to STP

% Difference: _____ Pass if % Difference < 10%

Aethalometer time: _____ Standard Time _____

Is the Aethalometer time within +/- 5 minutes? _____
If not, make note of the difference and if the time was corrected. _____

Is the date correct? _____
If not, make note of the difference and if the date was corrected. _____

Peform self-test? _____ Did everything pass the self-test? _____

Has the strip test been performed? _____

S0 =	S1 =	R0 =	R1 =
S0 =	S2 =	R0 =	R2 =
S Density =		R Density =	Balance =

Comments: _____

Form Revised 09-04-12

Form 2
API 633 Calibration/Audit Form

Aethalometer Annual Calibration / Quarterly Audit

Office of Air Quality - Air Monitoring Branch

Date: _____ Site: **Indianapolis - I-70E** AQS#: 18-097-0087

Start time: _____ End time: _____ Performed by: _____

Aethalometer Brand & Model: **Teledyne API / 633** Serial Number: **AE33-S01-00122**

Calibration Device Information

Flow Device SN: _____ Certification Date: _____

Thermometer SN: _____ Certification Date: _____

Barometer SN: _____ Certification Date: _____

As found calibration Through the Probe

Aethalometer Display: _____ lpm Observed Flow EPA Std

Flow Device Display: _____ lpm Qstd - Actual Flow

% Difference: _____ (see formula below)

≤10% = in cal, data valid; >10% but ≤15% = out of cal, data valid; >15% out of cal, data invalid

MFC Flow verfication "As Found"

F_{IN} (flow device)	F1	%	Fc	%
0.9 lpm _____	_____		_____	
3.0 lpm _____	_____		_____	
5.0 lpm _____	_____		_____	

Maintenance prior to "As Left Calibration"

Cleaned Optics area _____

Cleaned bug filter _____

Replaced Bypass Cartridge Filter _____ (As needed)

Leak Check

Through tape Flow _____ mlpm Leak check percent _____

Through pad Flow _____ mlpm

MFC Flow verfication "As Left"

F_{IN} (flow device)	F1	%	Fc	%
0.9 lpm _____	_____		_____	
3.0 lpm _____	_____		_____	
5.0 lpm _____	_____		_____	

API 633Calibration/Audit Form (Continued)

MFC Flow calibration IF NEEDED

	F_{IN} (flow device)	% (set pt - Qstd/Qstd * 100)
0.9 lpm	_____	_____
3.0 lpm	_____	_____
5.0 lpm	_____	_____

As left calibration check through the probe

Aethalometer Display: _____ lpm Observed Flow

Flow Device Display: _____ lpm Qstd - Actual Flow

% Difference: _____ Pass if % Difference < 10%

Aethalometer time: _____ Standard Time _____

Is the Aethalometer time within +/- 5 minutes? _____
If not, make note of the difference and if the time was corrected. _____

Is the date correct? _____
If not, make note of the difference and if the date was corrected. _____

Number of Tape Advances Left _____

Comments: _____

_____

_____

_____

Form Revised 05-14-15